The Journal of Systems and Software 101 (2015) 159–179

Contents lists available at ScienceDirect

The Journal of Systems and Software

journal homepage: www.elsevier.com/locate/jss

Quality of service approaches in cloud computing: A systematic mapping study

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ARTICLE INFO

Article history:
Received 7 January 2014
Revised 12 November 2014
Accepted 7 December 2014
Available online 12 December 2014

Keywords:
Quality of service
Cloud services
Systematic mapping study

ABSTRACT

Context: Cloud computing is a new computing technology that provides services to consumers and businesses. Due to the increasing use of these services, the quality of service (QoS) of cloud computing has become an important and essential issue since there are many open challenges which need to be addressed related to trust in cloud services. Many research issues have been proposed in QoS approaches in the cloud computing area.

Objective: The aim of this study is to survey current research on QoS approaches in cloud computing in order to identify where more emphasis should be placed in both current and future research directions.

Method: A systematic mapping study was performed to find the related literature, and 67 articles were selected as primary studies that are classified in relation to the focus, research type and contribution type.

Result: The majority of the articles are of the validation research type (64%). Infrastructure as a service (48%) was the largest research focus area, followed by software as a service (36%). The majority of contributions concerned methods (48%), followed by models (32%).

Conclusion: The results of this study confirm that QoS approaches in cloud computing have become an important topic in the cloud computing area in recent years and there remain open challenges and gaps which require future research exploration. In particular, tools, metrics and evaluation research are needed in order to provide useful and trustworthy cloud computing services that deliver appropriate QoS.

1. Introduction

Cloud computing is widely perceived to be an important new technology as a result of success stories from leading companies such as Amazon's EC2, Google's App Engine, GoGrid and Salesforce's Force.com. These companies provide services to users and businesses with attractive features such as low cost, reliability, availability, and flexibility of services (Zhang et al., 2010). Other features include the easy access to these services from any place through internet connection, high scalability of resources and application services, and the provision of shared resources between consumers as well as dedicated resources. According to the US National Institute of Standards and Technology (Mell and Grance, 2011), cloud computing is defined as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". This definition of cloud computing is commonly and widely used as a standard definition.

Though, cloud computing is now an established technology. However, due to increasing demand for cloud services and many consumers deploying and hosting all IT services to cloud computing it is thus difficult for consumers to select cloud services appropriate to their needs (Bouchenak, 2010). Nonetheless, consumers can select a cloud service appropriate for them from major service providers that can offer services with QoS. Consequently, cloud services have become very attractive to businesses but commercial offerings need to deliver the quality of service that is expected by consumers; if services do not reach their expectations, consumers will reject them (Hoßfeld et al., 2012). Furthermore, there is an increasing interest from both industrial and academic research communities and there are still many outstanding challenges with respect to QoS (Panzieri et al., 2011). Thus, the ability to specify the QoS is an important issue for consumers and service providers. However, there is lack of trust between consumers and service providers of cloud services and doubts about how consumers can have

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http://dx.doi.org/10.1016/j.jss.2014.12.015
0164-1212/

assurance that the service providers offer the QoS of the services (Nallur and Bahsoon, 2013).

In order to explore further, initial literature searches related to QoS approaches on the cloud computing topic have been performed. Based on these searches, we have found many articles on this topic suggesting the need for a formal mapping study to organise the literature into a useful body of knowledge. The main goals of this systematic mapping are to provide an inclusive overview, identifying potential research gaps that suggest areas for future research on QoS approaches in the cloud computing topic. A mapping study identifies and classifies research related to the software engineering field. The classification process provides information, such as publication frequency (per year and per publication source), and provides summaries and maps of the results to identify research topics suitable for further investigation (Budgen, 2008).

1.1. Study approach and contribution

We identified, analysed, and classified QoS approaches in cloud computing by means of a systematic mapping study (Petersen et al., 2008). Firstly, we identified 67 primary studies in the area of QoS approaches in cloud computing between 2008 and 2012, distributed through different publication sources (Table 2). For example, these sources included journals, conference proceedings, book chapters, and workshops. Secondly, we categorized the primary studies into three main classification schemes: research focus area (Section 4.1), contribution type (Section 4.2) and research type (Section 4.3). The research focus area is further categorized into five main focus area topics: software as service (SaaS), platform as service (PaaS), infrastructure as service (IaaS), cloud service provider (CSP), and cloud service consumer (CSC). In addition, each research focus area topic has been divided into subtopics (Fig. 3). Thirdly, the main findings of systematic mapping are presented into two facets; the first facet presents the research focus area with the contribution type and the second facet presents the research focus area with the research type (Section 5). In addition the detail findings (e.g., problem addressed, basic approach, limitation approach, validation and result of validation) of each proposed study on QoS approach in cloud computing has been discussed in the research focus area, contribution type and research type. Fourthly, a thorough survey of literature and detailed presentation of the studies is presented. We discover that many issues and challenges are still open and require more research attention. The contribution of this study can be classified into four main folds as follows:

(1) Identification of the primary studies and their publication sources.
(2) Classification scheme of QoS approaches in cloud computing into three themes of research focus area, contribution type, and research type.
(3) Systematic mapping findings of the current QoS approaches in cloud computing.
(4) Issues, challenges and future trends of the QoS approaches in cloud computing.

1.2. Related surveys

We have classified related surveys into three categories: (1) challenges of QoS based resources management, (2) challenges of QoS based software engineering and (3) systematic reviews and mappings.

(1) Challenges of QoS based resources management
A number of researchers have already reviewed the state-of-the-art and challenges of cloud computing in general and reported on the QoS in cloud computing within limited scope. Foster et al. (2008) compared cloud and grid computing from multiple aspects including how cloud and grid computing are similar in architecture, technology and vision and how they differ in other aspects such as the business model, programming model, applications and security. They discuss many future challenges that will face cloud computing services, such as resources management, cloud adoption, security issues, integration and the interoperability of services. In particular, they discuss how the main challenges of resources management are the QoS delivered to the users to locate or relocate the resources of applications, and the difficulty of achieving SLA requirements in terms of the cost effectiveness of systems provision and the monitoring of resources. Similarly, the question of how QoS in cloud computing contrasts with the historical background of QoS in grid computing was considered by Armstrong and Djemame (2009) with a specific focus on the management and performance of resources.

Furthermore, Buyya et al. (2009) proposed the resources method of clouds from a market-oriented view and presented a new vision of universal cloud exchange for commercial services. In addition, they discussed the state-of-the-art of cloud platform aspects, such as the limited support for resources management from a market-oriented perspective, the lack of negotiation between providers and users to fulfil SLAs, the lack of models and limit mechanisms of the virtual machine resources allocated to meet SLAs, and the need to manage risks related to SLA violation. In addition, interoperability issues between various cloud service providers requiring interaction protocols were discussed. Furthermore, they identified the need for programming environments and tools to enable the development of cloud applications. Moreover, Dillon et al. (2010) reported the issues and challenges of cloud computing in general. They reviewed cloud adoption issues such as security and the costing and charging model. Since consumers of the cloud do not have authority and control of the underlying cloud resources, service providers are required to ensure the QoS (availability, reliability and performance) of the resources. Therefore, the issue of the SLA definition and specifications must be addressed in a suitable way that covers the consumers' expectations. In addition, advanced mechanisms in the SLA are required for user feedback. However, the study by Dillon and Chang concentrated more specifically on interoperability issues. Similarly, the state-of-the-art implementation and design challenges of cloud computing were discussed by Zhang et al. (2010), including automated service provisioning, virtual machine deployment and server consolidation. In relation to the challenges in automated service provisioning, the study highlighted the difficulties for service providers in achieving service-level objectives such as QoS requirements to allocate and de-allocate resources with minimum operational costs.

(2) Challenges of QoS based software engineering
The importance of combining the cloud computing and services paradigms and how a software engineering framework can help service providers to combine these paradigms was discussed by Yau and An (2011). They argued that more research was needed on software engineering for cloud computing to address the challenges such as QoS management and security. They also discussed the main challenges and issues in application development using service-oriented software engineering, such as confidentiality and integrity, service reliability and availability, and QoS monitoring. For QoS monitoring, it is difficult to manage different QoS requirements because multiple providers with different approaches need to manage the services and the different workflows required to host services dynamically. Moreover, Vazquez-Poletti et al. (2013) discussed many cloud computing challenges related to